View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Elsevier - Publisher Connector

Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 14 (2016) 993 – 1002

Transportation Research Procedia

www.elsevier.com/locate/procedia

6th Transport Research Arena April 18-21, 2016

Cloud based HPC for innovative virtual prototyping methodology: automotive applications

Fouad el Khaldi [a,*], Christian Ahouangonou [a], Matthieu Niess [b], Olivier David [c]

[a]*ESI GROUP, 99 rue des solets, 94513 Rungis, France*
[b]*GESTAMP, 17-19, Rue Jeanne Braconnier, 92360 Meudon, France*
[c]*BULL, Rue Jean Jaurès, 78340 Les Clayes sous bois*

Abstract

The objective of the paper is to describe how the cloud based HPC services help to investigate the behavior of automotive part components involved in structural crash and NVH test simulation.
Currently, market requirements related to vehicle weight reduction and cost cutting are driving the industry to accelerate their innovation and to introduce new design and new material and manufacturing processes. The challenge for supply chain is to handle conflicting requirements and bring revolutionary changes to vehicles, while at the same time cutting the development costs and time drastically.
Business scale-up is one of the main competitiveness factors. This required mastering an efficient and flexible process for customization and localization. Divergence of the models are inherent phenomena with the current silo approach due to the complexity of the interactions; CAD-CAE, CAE-CAE.
Methodology: To answer this challenge, we will apply Virtual Prototyping with a rather holistic view, several full vehicle simulation models all based on one unique central Body In White subsystem, named the Single Core Model approach. This disruptive approach will enable to support collaborative decision making process during the Product Development phase; including engineering stakeholders from 3 different disciplines: Crash & Safety, Durability, NVH. The use of HPC cloud services will also be a huge benefit for multi-site companies. Indeed, Gestamp R&D Centers located in Spain, France and Sweden have increasing needs in handling projects over several locations. Therefore, the HPC enables to access and share the data, to run simulations and to analyze the results in all the relevant locations through a conventional web browser. In summary,

* Corresponding author.
E-mail address: fouad.el.khaldi@esi-group.com

2352-1465 © 2016 Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)
doi:10.1016/j.trpro.2016.05.079

this HPC cloud application will enable a more efficient project handling by reducing data transfer time and by improving the communication between the different stakeholders of a project.
Limitations of this study: Therefore, this innovative development methodology calls for extensive computer resources, which was considered as a major obstacle to go through this experience. Cloud Computing seems to be the ad-hoc solution as of today for fast growing manufacturing companies like GESTAMP. This is a major enabler; it offers the necessary flexibility to access to HPC resources when it is needed at an affordable cost.
Results: The experiment was run on extreme factory, Bull's HPC on-demand compute service, which gave Gestamp the easiness, performance and flexibility that they needed to perform their work.
Conclusions: This experiment is part of European FP7 – Fortissimo project, it showed how to avoid last minute engineering design changes, and it should result in improved competitiveness in order to reduce the development period, to shortening time to market, to improve quality at competitive pricing.

© 2016 Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

Keywords: Virtual Prototyping; simulation; HPC Cloud; vehicel design; CO_2 reduction; crash & safety; stifness; durability; Single Core Model; HPC Cloud; concurrent

1. Summary

The objective of this Fortissimo experiment is to prove the concept and demonstrate the benefits of the use of Cloud-based-HPC services to investigate the behavior of automotive components in a structural performance test simulation using an industrial software package. It is a collaborative approach based on Single Core Modelling, using the Virtual Performance Solution Software Suite from ESI Group running on the Extreme Factory system from Bull.

The design of vehicles involves trade-offs between conflicting requirements such as weight reduction, performance requirements and manufacturing constraints. To answer this challenge, Virtual Prototyping was adopted with a holistic view in which several full vehicle simulation models, all based on one unique central Body In White subsystem, were used. This is called the Single Core Model approach. This disruptive approach enables a collaborative decision-making process to be supported during the development phase.

Currently, market requirements related to vehicle weight reduction and cost cutting are driving the industry to accelerate their innovation and to introduce new designs, new materials and new manufacturing processes. The supply chain challenge is to manage conflicting requirements and bring revolutionary changes to vehicles, while at the same time drastically cutting the development costs and time to market.

Business scale-up is one of the main competitiveness factors. This requires mastering an efficient and flexible process for customization and localization.

Divergence of the models are inherent phenomena with the current silo approach due to the complexity of the interactions; CAD-CAE, CAE-CAE. To meet this challenge, we propose the Single Core Model approach; a holistic solution using Virtual Prototyping for full vehicle simulation. This disruptive approach will enable to support a collaborative decision-making process efficiently during the Product Development phase; including engineering stakeholders from different disciplines, such as Crash & Safety, Durability, NVH. This Single Core approach allows more efficient project management by reducing the process complexity due to models duplication and data transfer time and by improving the communication between the different stakeholders, for multi-site companies.

At present, this innovative development methodology calls for extensive computer resources, which was considered as a major obstacle to complete this experiment. The use of HPC cloud services seems to be the ad-hoc solution as of today for fast growing manufacturing companies like Gestamp. This is a major enabler to access and share data, to run simulations and to analyze the results across the relevant locations using a conventional web browser. It offers the necessary flexibility to gain access to HPC resources when needed at an affordable cost.

The experiment was run using Extreme Factory, Bull's HPC on-demand compute services, which gave Gestamp the easiness, performance and flexibility that they needed to perform their work. This experiment is part of EU's Fortissimo project and it showed how to avoid last minute engineering design changes. It should result in improved competitiveness: reducing the development period, shortening time to market, and improving quality at competitive pricing.

2. Introduction

The Green Vehicle initiative is a major driver for the automotive industry to answer environmental requirements and regulations. This challenge calls for disruptive innovation in vehicle design and materials. Steel remains the main cost effective material for Body In White mass production for the foreseeable future. This challenge is a good business opportunity for the emergence of new industry leaders like GESTAMP, who have developed a new grade of steel called Press Hardening with the associated manufacturing processes. It is one of the major innovations successfully introduced to the market in answer to the weight reduction constraints of the vehicle with recognized world-wide advantages.

However, the industrialization and the customization of this innovation also requires new design and development processes in order to enable engineering & business trade-offs between conflicting requirements such as weight and cost reduction, passive safety enhancement and manufacturing constraints.

Business scale-up is one of the main competitiveness factors. This required mastering an efficient and flexible process for customization and localization.

Divergence of the models are inherent phenomena with the current silo approach due to the complexity of the interactions; CAD-CAE, CAE-CAE. To answer this challenge, we propose a holistic solution using Virtual Prototyping, several full vehicle simulation models all based on one unique central Body In White subsystem, namely the Single Core Model approach. This disruptive approach will enable to support collaborative decision making process during the Product Development phase; including engineering stakeholders from different disciplines and regulations requirements: Crash & Safety and Static Stiffness. Figure 1 illustrates the drawbacks of the traditional silo approach and the single Core Model concept.

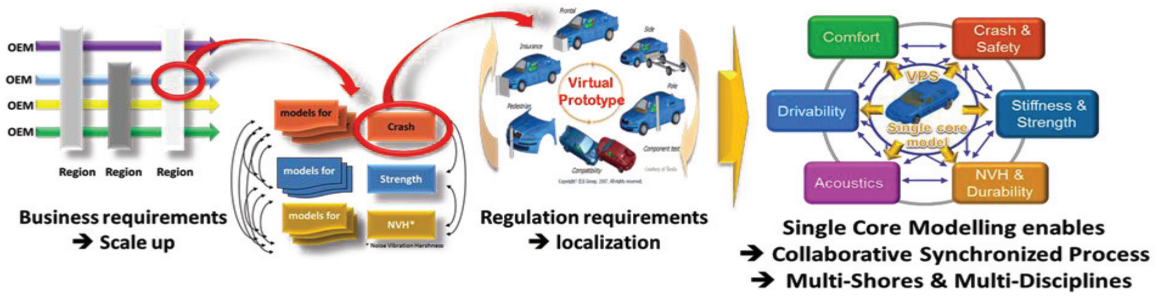

Fig. 1. Silo Approach and Single Core Model advantages.

Single Core Modelling will reduce the CAD-CAE synchronization efforts, and eliminate the conversion & consolidation between different CAE-CAE Models for Design reviews and trade-offs. Today’s approach is a very time-consuming task and a source of errors. The Single Core Model approach will replace human efforts by computing resources on low value tasks. This approach will enable a reduction in the effort required for Full Vehicle Model handling directly related to the number applications involved. Thus, it will enable better use of engineering expertise to improve product quality.

This breakthrough will help to take into account the regionalization and customization constraints upfront, to avoid last minute engineering design changes, and should result in a shorter ramp-up phase and improved competitiveness.

3. User requirements

Gestamp's user requirements are, on one hand to improve the handling, the interaction and the lead time of full vehicle numerical models used by several disciplines, and, on the other, to evaluate the use of an HPC cloud to run Crash, Static and NVH Finite Element simulations. Based on these needs, we defined the performance and validation criteria for the experiment. Table 1 illustrates typical Key Performance Indicators for targeted performance of the Single Core Model Solution implementation in an industrial context. The HPC Cloud is an excellent opportunity, but software access, adaptation and upgrades will be needed. In order to reach these performance targets in particular a sustained, heavily repetitive iterative mode needs to be supported, which should reach the target of a maximum of 4 hours per iteration.

3.1. Single Core Model Concept

Figure 2 illustrates the traditional generic organization with non-shared includes between models of different applications and load cases which require updating all includes separately in each model. Hence, the same task would need to be repeated several times, which leads to possible divergence errors in the prepared model and especially to a waste of time. This is exactly what the Single Core Approach is able to avoid. Compared to the previous structure, with the Single Core Model, detailed in Figure 3, each model keeps the master file with the include organization. One of the differences is that at least one include (the Body In White include) is shared by all models. Besides this update, all includes and all models parameters are fitted in order to accept BIW updates without needing to open every model to make the changes.

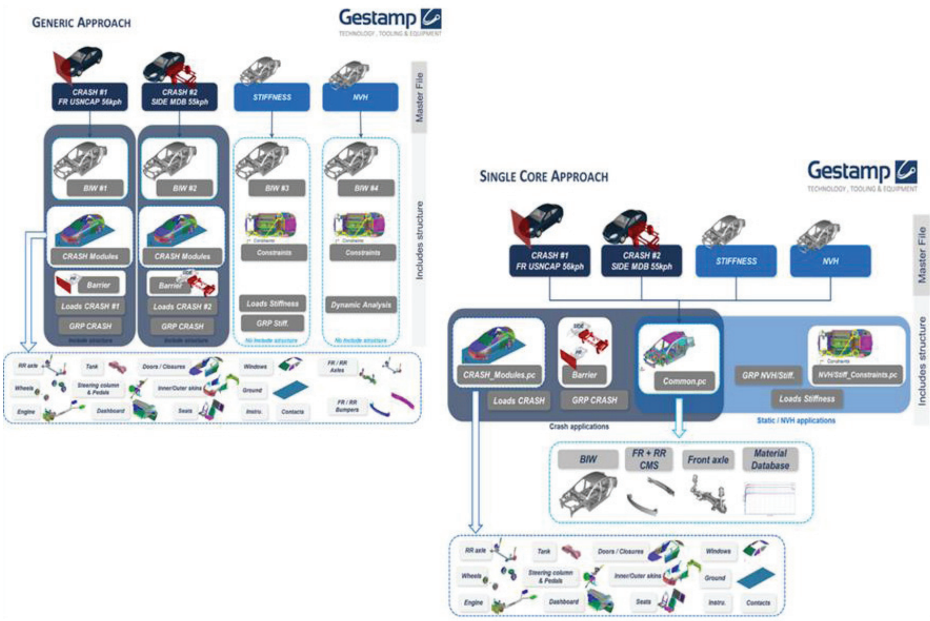

Fig. 2. Generic model structure vs. Single Core structure.

3.2. Enabling software for cloud

Static and NVH models are usually based on a coarse model. Moving to the Single Core model, the model sizes increase in order to unify the model representation of the different domains (Crash, Static and NVH); thus requiring higher CPU resources. The HPC-Cloud enables the access to necessary computing resources to meet these business requirements. However, the current NVH solver performance needs to be improved to handle larger models in order to leverage the benefits of the Single Core Model methodology. The Cloud based HPC architecture requires a highly scalable solver to allow efficient software use of the resources and to deliver results quickly, it also requires high transfer volumes for the simulation data.

Three kinds of performance are targeted: CPU, Memory and IO optimization to avoid read/write of over-sized files. Based on that adaptation, enhancement and upgrade the overall solver performance improvements enable the experiment to reach the performance metric as defined in Table 1.

Technical environment validation (HPC Cloud)

Jobs have been performed on extreme factory HPC cloud with BULL clusters. Processing was performed as follows:

- Data upload
- Job submission
- Run control (Info/Warning/Error messages)
- Data download

As this procedure is now well known, it will be possible to use such remote cluster services as a production tool.

Remote visualization was not available due to Gestamp IT security recommendations: opening network ports is not compliant with internal security rules, especially with ports ranges involved.

3.3. Baseline Body In White definition

The start of a co-development project is in most cases linked to the reception of OEM shared data. This data can be provided under different format types, from the simplest with only Bill Of Material and CAD data, to the richest with a full vehicle crash simulation model with CAD data. The shared concept always represents the starting point of the study, the solution optimized by the OEM that is usually validated in all load cases. The goal of the Gestamp optimization process consists in the development of an alternative concept that should be lighter and more cost--effective than the described baseline, but achieving the same performance requirements.

Pillars and rails depictured in Figure 4 represent the structural parts that are the most commonly studied in our Co-Development projects. The yellow front rails are the most important load carrying set of parts for frontal crash impact, the clear and dark blue pillars with purple rocker for lateral crash and the orange rear rails for rear crash impact.

Thus, in order to define a meaningful baseline for this business case, it has been chosen to create a Body In White reference concept that would match the average employed Design configuration (thickness, material and design) that have been observed during a benchmark of the typical OEM Body In White in year 2014.

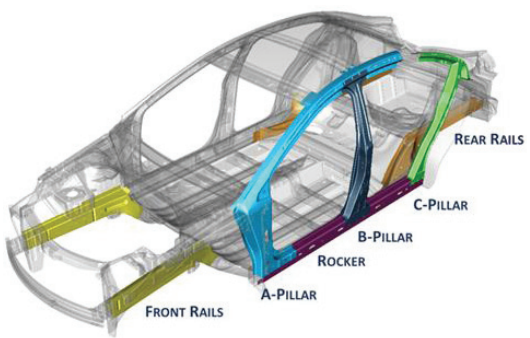

Fig. 3. GLAB10 Body In White main structural parts.

The result of this benchmark can be observed in Figure 4. Most of the structural parts of the Body In White use cold stamped steel with an Ultimate Tensile Strength (UTS) between 400 MPa and 1200 MPa. It should be noted that that Press Hardened Steel (in Red) with UTS of 1500 MPa is already used by several OEMs, especially in A-, B- and C-Pillar area.

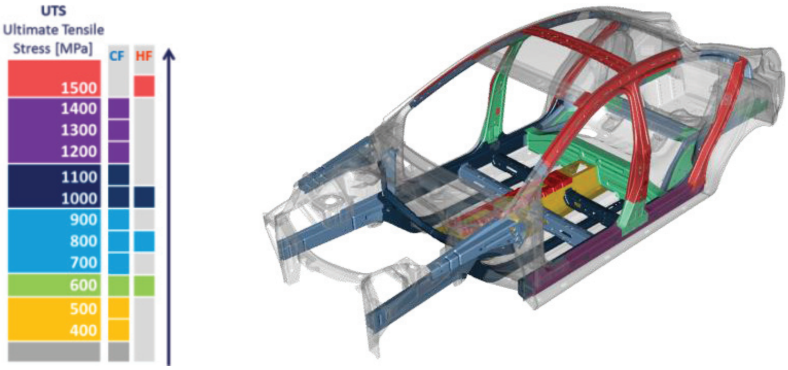

Fig. 4. GLAB10 Body In White baseline with associated material grade strength.

3.4. Baseline BIW performance investigation

To demonstrate the Single Core Model effectiveness in our business case, it has been decided to use four applications that are commonly used for Body In White validation and that also represent the simulation area of Co--Development projects:

- Crash domain – USNCAP Side Impact MDB 55 kph (Full Vehicle)
- Crash domain – USNCAP Frontal Impact 0° 56 kph (Full Vehicle)
- Static Domain – Stiffness Analysis (Body In White)
- NVH Domain – Modal Analysis (Body In White)

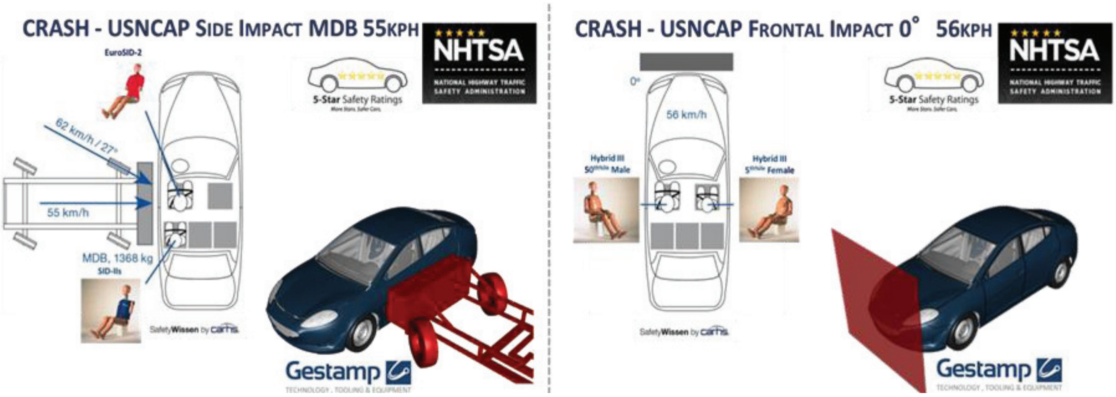

Fig. 5. Applications used as examples in the business case – load case details.

3.5. Final Gestamp BIW lightweight validated concept through BIW optimization

Starting from the baseline Single Core Model, the latest innovations in terms of material and processes have been implemented into the GLAB10 Body In White. Technologies such as Press Hardening with tailored properties also called Soft Zones (applied on B-Pillar, Front Rails Inner & Outer), Tailor Welded Blanks Press Hardening USIBOR1500/DUCTIBOR500 (applied on Rear Rails) and Press Hardening with patch (applied on B-Pillar) all participate in the lightweight design of this optimized Body In White (see material grade distribution on Figure 7).

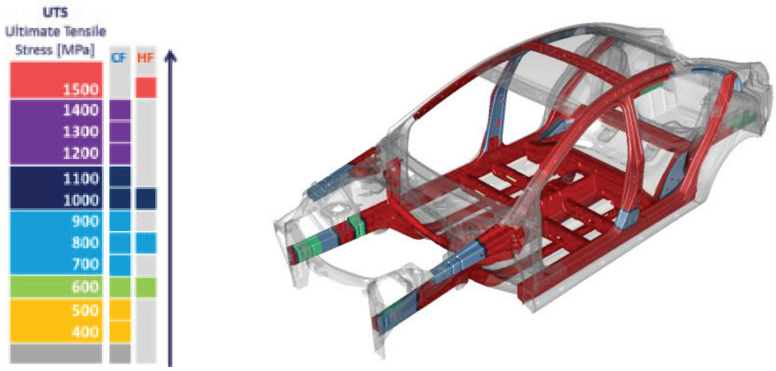

Fig. 6. GLAB10 Body In White optimization with associated material grade strength.

With many years of experience and know-how with the manufacturing process of hot stamped steel, Gestamp is one of the pioneers in this manufacturing process. Significant investments have been made over the past years aimed at developing and extending this technology around the world, enabling them to meet a growing demand from automobile manufacturers for all Body In White products. As a consequence of that, Gestamp became the world's largest supplier of hot-stamping parts.

Through the use of this know how in terms of hot stamping products combined with ESI's Co-Development project experiences, we were able to put the right material with corresponding thickness at the right place and thus to significantly reduce the thicknesses of most of the structural parts, by achieving similar performances as the reference in both crash requirements. The global Body In White weight for the baseline is 322 kg. The use of Press Hardened Steel enables to come down to a weight of 290 kg, about 10% weight saving on the whole Body In White.

Finally, the Single Core approach combined with HPC cloud solution enables us to achieve lightweight Press Hardened optimized Body In White validated in four automotive simulation domains: frontal crash, side crash, static stiffness and NVH. The optimization loops cycles to reach similar performances with our leading technology, starting from a conventional BIW, have been considerably accelerated through the use of a single Body In White, the heart of the Single Core Models.

4. Achievements

4.1. Simulation results

The overall NVH improvement of the full automotive Body-in-White showed a factor of 70% time reduction for the industrial model running on 8 cores.

This performance will enable us to run the case in an industrial context. It means it could run in less than 1 hour by allocating 16 Cores. HPC on the cloud will offer these resources flexibly and at affordable cost.

This allows to speed up the design changes verification and validation in order to meet the business requirements.

No further scalability tests were tried with more cores as the dimensioning factor is the memory available for the run (2 × 128 GB).

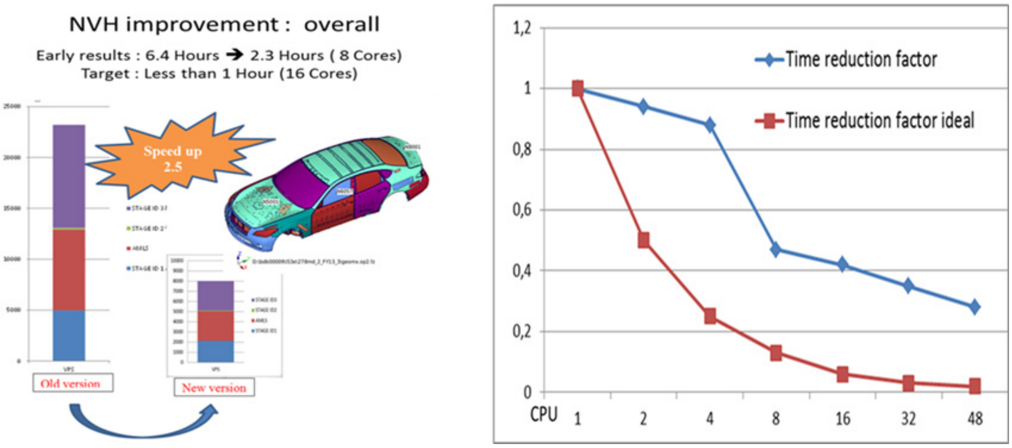

Fig. 7. NVH improvement.

4.2. Cloud licensing

BULL is the hardware provider with its extreme factory service. An end user will use extreme factory to run ESI Group software. The new system for managing the license will support individualization of users. The different companies will be managed with their own rights.

The following image shows globally how the system will work:

- The user (company) buys a license from ESI and receives an identification key. This key will be used to identify the user when he runs a simulation on extreme factory.
- The scope of the prototype concerns the usage of this license bought by a client. The purchasing process will not be covered here.

The following lines describe the different steps that the system will follow to process the simulation in the cloud:

1. The user connects to extreme factory to run ESI solver, then he will give his identification key as one of the parameters of the run,
2. Once the runs begins, the application will check for the valid license:
   a. An Https request is sent to the web service shown on the right side of the image above. Some information will be provided with the request (Company name, user name, Identification key,…)
   b. After checking the web service will send a reply. If the request is valid, the system will send the application all the information needed for the run (dedicated license file).
   c. Then the application will run the calculation on extreme factory.

The benefits will be measured in 2 distinct ways: First in terms of time saving thanks to the leverage of HPC resources which enable the introduction of the Single Core Modelling as new collaborative engineering approach to support Decision making process. A second natural benefit is the overall financial gain which can be obtained by using the HPC Cloud just for the time necessary to complete the run, instead of provisioning hardware, staff and licences for the whole year. Quantifying this financial benefit is dependent on overall simulation usage at the customer site, and utilization ratios of its HPC infrastructures.

Single Core Modelling enables the handling of only one Body In White numerical model for several applications (four applications in our example). Thus, once concepts of Body In White have to be updated, instead of implementing the changes in the 4 former models, only one single core model needs to be modified. Time spent on setting up and afterwards updating the model is then divided per 3.5 to 4 (see table below). Indeed, the simulation model setup for one application lasts approximately 50 hours, so 200 hours for all four applications. With the Single Core Model, only 60 hours are needed to build up the Core Model (10 hours more due to the higher complexity of the system). Moreover, as only one Core Model is used, the risk of having four divergent models, in terms of concepts, is consequently reduced to zero. The compute cost difference between a classic crash model and one using the Single Core approach is close to zero. Thanks to this innovative approach, the expert team involved in such tasks will be able to spend more time in developing and optimizing lighter and better cost-effectives solutions for Body In White.

Table 1. Typical benefits of Single Core Approach.

Time Saving/Single Core	Application dedicated models				Single Core Model
	Crash		Stiffnesss	NVH	Crash/Stiffness/NVH
	Front	Side			
Set Up	50 h	50 h	50 h	50 h	60 h
Maintenance & Evolution	1–4 h	1–4 h	1–4 h	1–4 h	1–4 h
Model Convergence percentage for several test cases	30%	30%	30%	30%	100%
Synchronization CAD-CAE	Need to do it 4 times				1 time
Synchronization CAE-CAE	Need to do it 4 times				1 time

The use of HPC cloud services will also be a huge benefit for multi-site companies. Indeed, Gestamp R&D Centers located in Paris (France), Luleå (Sweden) and Barcelona (Spain) increasingly needs to manage projects over several locations. Consequently, HPC enables to access and share the data, to run simulations and to analyse the results in all the relevant locations through a conventional web browser. In summary, this HPC cloud application will enable a more efficient project handling by reducing data transfer time and by improving the communication between the different stakeholders of a project.

5. Conclusion and perspectives

The use of HPC resources have allowed to run those four types of models with same sharp detail level linked to Single Core modelling. Indeed, those four application fields demonstrated the efficiency of such an approach: model build-up time has been divided by four; previous risk of divergences in the four models is now reduced to zero. Thanks to this innovative approach, the expert team involved in such tasks will be able to spend more time in the product optimization phase.

Using HPC cloud services will also be a huge benefit for multi-site companies. Indeed, Gestamp R&D Centers increasingly need to manage projects over several locations. Consequently, HPC enables to access and share the data, to run simulations and to analyze the results in all the relevant locations through a conventional web browser. In summary, this HPC cloud application will enable a more efficient project management by reducing data transfer time and by improving the communication between the different stakeholders of a project.

These positive conclusions will lead Gestamp to further develop this Single Core approach on GLAB10 demonstrator, combined with HPC Cloud services as driving innovation for the development and the optimization of lighter and more cost-effective solutions for Body In White.

As a first output this experiment has helped to validate the specifications and the 100% Minimum Requirements for the platform needed to provide the expected services. The diagram below gives an overview of the main modules and workflow.

This experiment showed that the HPC Cloud benefits are not limited to flexible access to HPC resources, and providing flexible services at an affordable, competitive cost.

In fact, the HPC-Cloud will most likely be a key enabler or accelerator for disruptive changes with a deep impact on a company's competitiveness. It will enable the upgrade of a company's overall Process & Methodology to leverage the new potential for Virtual Prototyping.

The Fortissimo experiment was a typical example of this disruptive methodology. It showed how the HPC Cloud enables efficient support for Gestamp specialization in their unique competence in the Hot Forming Value chain.

The Single Core Model is a key enabler to capitalize on this competitive differentiator by scaling on the world-wide market accounting for the local and regional market requirements.

The Fortissimo project helped ESI Group to validate an industrial service approach and to adapt the methodology for Gestamp's specific business context.

In addition to the Product portfolio, this customized service will be available for the industry partners during the deployment phase. It will enforce their smart specialization.

Cloud Based HPC lowers the barrier of the initial investment to implement the Virtual Prototyping methodology, in particular for Mid-Caps, SME's and also start-ups. This experiment gave good indications on how to the leverage the current solution portfolio and Customers' installed base needs for new methodologies. Figure 8 illustrates the depth and breadth of the potential HPC-Cloud market for Virtual Prototyping.

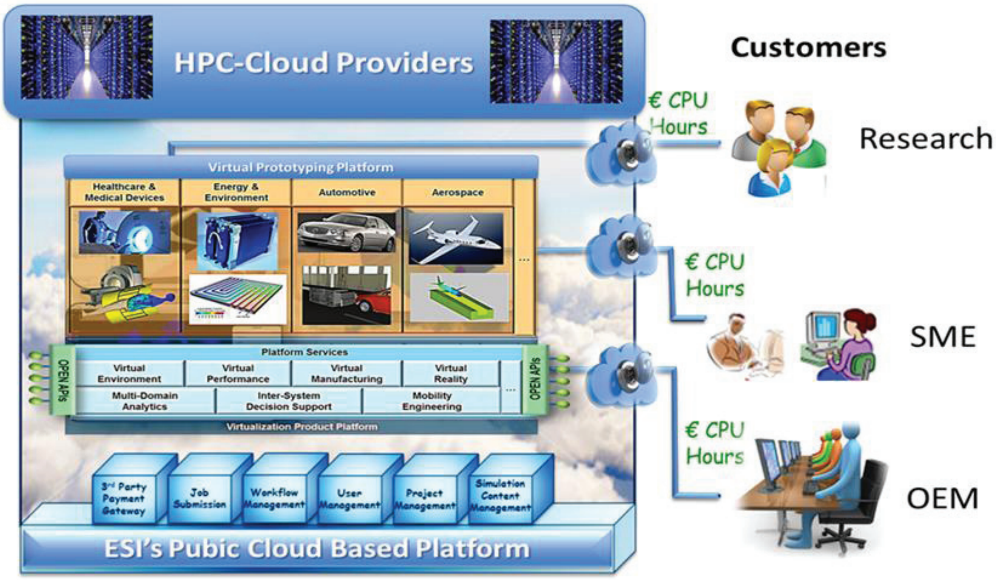

Fig. 8. Virtual Prototyping – Cloud Based Platform.

Acknowledgements

Acknowledgement of EC funding: This project has received funding ***from the European Union's Horizon 2020 research and innovation programme under grant agreement*** **Fortissimo project *n*°609029 under the 7th Framework Programme.**

Disclaimer: The dissemination of results herein reflects only ***the author's view and the Commission is not responsible for any use that may be made of the information it contains".***

References

Araki, T. (2014), Nissan Motor CO. LTD. Vision, Zero defect in physical test by CAE, EGF, Paris.

Cazes, C., Leroy, E., Niess, M. (2014), EGF, Paris, GESTAMP GLAB project Overview.

El Khaldi, F. & all (2010), Recent integration achievements in virtual Prototyping for Automotive industry, Fisita, Budapest.

El Khaldi, F. & all (2011), Evolution from Realistic Simulation to new paradigm of collaborative Interactive Virtual Prototyping, Nafems World Conference, Boston.

El Khaldi, F. (2014), I4MS, Fostering Digital Industrial Innovation in Europe, Berlin.

Landel, E. (2014), Renault: Simulation factory: a way to face complexity for numerical modelisation, EGF, Paris.

Sundermeier, R. (2014), Volkswagen AG; Computational Calculation: from problem to process, EGF, Paris.